fischer

# Installation Manual.

C-Fiber Force Strengthening System
with FRS-L-S and FRS-L-H
Externally Bonded CFRP Laminates.

EN

**Safety Instructions**
Please read the Safety Data Sheets (SDS) and Technical Data Sheets (TDS) before using the products! When working with chemical products, use suitable protective clothing, protective gloves and safety glasses. IMPORTANT: Please follow the application instructions, which are included in every package.

 These application instructions were created with care. However, fischerwerke GmbH & Co.KG does not take over any liability for any errors in these application instructions and their consequences. There is also no liability for direct or consequential damage taken from incorrect use of the products.

Performance of construction materials (Epoxy resins) vary with external conditions (e.g. project site conditions such as temperature or humidity).

The suitability of the strengthening kit must be checked and confirmed by the responsible planer. All product names and brand names used belong to the owner, even if not explicitly marked as such. The content is subject to changes.

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## Content

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# 1 Introduction

This installation manual describes the safe use of fischer FRS-L-S and FRS-L-H externally bonded (EB) CFRP Laminates. This document must be used or referred to in conjunction with all relevant Technical Data Sheets (TDS), Safety Data Sheets (SDS), Technical Assessments and project specifications. Structural strengthening works shall only be carried out by experienced and trained specialists. For professional product trainings and in case of any questions about our design software REINFORCE-FIX©, please consult the technical team of the national fischer subsidiaries. Note that the inadequate choice on the strengthening or retrofitting method, incorrect structural design, inadequate installation might cause significant risks.

# 2 System description

## 2.1 Intended use

The primary intended use of the fischer C-Fiber Force Strengthening System with externally bonded CFRP Laminates is the strengthening of reinforced concrete or pre-stressed concrete structures. The fischer C-Fiber Force Strengthening System was developed for safety relevant applications. The design and application of CFRP Laminates on other base materials such as timber or masonry require engineering judgement.

*The manufacturer strongly recommends the use of the fischer C-Fiber Force Strengthening System as a whole. Combined applications with products from other manufacturers are out of the responsibility range of the fischer group.*

## 2.2 References

This installation manual was written in accordance with the recommendations in ACI 440.2R (2017) and the DAfStb Guideline (Strengthening of concrete members with adhesively bonded reinforcement, Part 3: Execution, 2012).

## 2.3 Restrictions

This product shall only be used for its intended purpose. Further design details or design information are to be found in the structural design, technical drawings, specifications and risk assessments of the corresponding design engineer or specialist contractor.

# 3 fischer C-Fiber Force Strengthening System

The primary intended application scope of the fischer C-Fiber Force Strengthening System is to strengthen reinforced or pre-stressed concrete members. The FRS-L-S and FRS-L-H externally bonded CFRP Laminates are system components of the fischer C-Fiber Force Strengthening System.

Table 1: Constituents of the fischer C-Fiber Force Strengthening System with corresponding short product descriptions

| Product name | Description |
|---|---|
| FRS-L-S & FRS-L-H<br>FRS-L-S NSM | Pultruded, precured carbon fiber reinforced polymer (CFRP) Laminates for the structural strengthening |
| FRS-CS | Thixotrophic, 2-component structural bonding agent for the installation of CFRP Laminates and steel plates |
| FRS-W U300<br>FRS-W U600 | Unidirectional Carbon Fiber Fabrics with 300 g/m$^2$ or 600 g/m$^2$ area density |
| FRS-FC | Unidirectional open end high-strength carbon fiber anchor for optimal end-anchorage of Carbon Fiber Fabrics |
| FRS-CF | Thixotropic, 2-component epoxy-based saturating resin for the application of FRS-W and FRS-FC |
| FRS-PC 11 | Thixotropic, high-viscosity, low-shrinkage, 3-component epoxy-based concrete repair mortar for reprofiling, surface levelling and for increasing or restoring concrete cover |
| FRS-BA | 2-component, epoxy-based, solvent-free high performance bonding agent for optimal adhesion between different concrete repair mortars and existing concrete as well as corrosion protection for embedded steel reinforcing bars |
| FRS-CP red<br>FRS-CP grey | Low viscosity, 2-component, epoxy-based corrosion protection primer for exposed steel surfaces as well as embedded steel rebars in two colour versions, red and grey |
| FRS-SF | Highly UV resistant and water repellent, waterborne protective coating with high durability against environmental exposure for CFRP reinforcement in outdoor applications. |
| FRS-FP | Waterborne, intumescent coating for CFRP strengthening systems against fire and smoke development |
| FRS-CA | Universal cleaning agent for the FRS-L-S, FRS-L-H, FRS-L-S NSM, CFRP Laminate and tools |

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# 4 Certification and technical assessments

The intended use of the fischer C-Fiber Force Strengthening System using externally bonded CFRP-Laminates is regulated by:

- ICC-ES Evaluation Report (ESR-4774) “Concrete Strengthening using the C-Fiber Force Strengthening System”
- European Technical Assessment (ETA-24/0281) according to the European Assessment Document EAD 160086-01-0301 “Kits for the strengthening of concrete elements by externally bonded and near surface mounted CFRP strips”.

# 5 Storage conditions

The materials shall be stored in closed and undamaged original packaging in a dry environment at ambient temperature. Please note the minimum and maximum storage temperature and the shelf life in the corresponding product data sheets (TDS) and product labels.

The FRS-L-S and FRS-L-H CFRP Laminates shall only be transported in the original packaging or with other adequate protection against mechanical and chemical damage.

# 6 Recommended equipment

## 6.1 Equipment, devices, tools and accessories

The adequate installation of the fischer C-Fiber Force Strengthening System, it is recommended to have the following equipment on site:

- Humidity meter
- Equipment for measuring the moisture content of components e.g. concrete moisture meter (CMM)
- Thermometer for air and surface temperatures
- Crack width ruler
- Concrete surface tester to determine the surface unevenness
- Concrete pull-off tester including steel disks with a diameter of 50 mm disc to determine the concrete tensile strength, adequate adhesive for installation.
- Diamond core drilling machine and accessories (for concrete pull-off tests)
- Concrete scanner to determine concrete cover and / or position and/or diameter of rebars
- Weighing scale with suitable weight range and precision
- Equipment for substrate preparation (by caulking, blasting, grinding and for cleaning work)
- Handheld agitator suitable for mixing the chemical products, with a rotation speed (≤ 300 rpm)
- Application equipment
  (Trowel, spatula, steel brushes, adhesive application device, cleaning cloth, etc.)
- Ruler and visible marker
- Wet film thickness gauge

## 6.2 Cleaning of tools and accessories

All tools and processing accessories must be cleaned immediately after use with FRS-CA Cleaning Agent or another suitable solvent. Cured materials can only be removed mechanically.

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# 7 Health and safety

## 7.1 Risk assessment

All health and safety risks must be assessed and adequate countermeasures shall be defined. This includes the very condition of the structure and the resulting risks thereof, the processing of all materials used on site as well as working methods.

All work and working procedures must be carried out in full compliance with the relevant local safety and environmental regulations in force on site.

## 7.2 Personal safety

During the installation, safety shoes, safety gloves and other suitable skin protection must be always worn. It is strongly recommended to use adequate disposable safety equipment during the processing and application of the materials. Since epoxy adhesives or saturating resins can cause skin irritation, always wear protective gloves e.g. nitrile-based hand gloves when working with them. Unprotected skin must always be covered with protective cream before starting work.

Always wear suitable eye protection during processing, mixing and installation of the products. It is recommended to carry eye wash with you at all times. Always wash hands with suitable soap and clean water after processing the materials.

The work area must be well ventilated, and workers should take regular breaks in the fresh air, to avoid health problems. The developing dust and quartz sand during drilling, grinding or sandblasting the concrete can be hazardous. Avoid to inhalation of concrete or CFRP dust. To protect yourself and others, use e.g. vacuum cleaner or other adequate suction techniques. Always wear a dust mask or respirator when grinding concrete or cutting the CFRP Laminate. For detailed health and safety information, see the relevant SDS.

## 7.3 First aid

If the epoxy mortar-based chemicals come into contact with the eyes or mucous membranes, contact lenses must be removed and the eyes must be rinsed immediately with clean, warm water for 10–15 min. and a medical doctor should be consulted.

If chemicals come into contact with the skin, it must be cleaned immediately and carefully rinsed with clean warm water.

In case an accident happens, despite all of the preventive measures, the corresponding SDS must be immediately handed over to the emergency services. This helps the emergency services to select the appropriate medical treatment(s). For detailed health and safety information, refer to the relevant SDS of the individual products.

## 7.4 Waste disposal

Excess materials must not be poured down in drains or into water supplies. Waste and packaging must be disposed by specialized waste management companies or partners in accordance with local legislation and official requirements. Furthermore, chemical materials must not enter the soil, watercourses, drains or sewers. Chemical waste in uncured form or leaking adhesive must be disposed as hazardous waste.

Waste in the form of cured adhesive can be safely disposed off as normal construction waste in accordance with local legislation. For detailed environmental and safety information, refer to the relevant SDS.

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# 8 Installation steps

## 8.1 Preparation works, substrate and environmental conditions

**Requirements and preparation**

**Environmental conditions**

- Verify the residual moisture content of the concrete using an adequate device (e.g. CCM)
- The residual moisture content of the concrete shall not exceed max. 4 % by weight of concrete grade C30/37 and 3 % by weight for concrete grade C35/45, measured with a CM device in accordance with ACI 503.4.
- The residual moisture content of the concrete shall not exceed max. 4 % by weight according to the DAfStb Guidelines (Strengthening of concrete members with adhesively bonded reinforcement, Part 3: Execution).
- Verify the permitted temperature range of the member with a thermometer
- Verify that the chemicals are stored at the permitted storage temperature before use.
- Underground temperature of the member to be strengthened should be higher than +10 °C and at least 3 K above dew point during and after application throughout the curing time.
- The maximum temperature should not exceed 40 °C and the relative humidity should be below 75 %. Check the humidity with an adequate humidity measurement device.

## Requirements and preparation

### Concrete substrate conditions

Concrete patching / Concrete Reprofiling / crack injection / corrosion inhibition works on the substrate may be necessary prior to the application of the CFRP Laminate if[1]:

- There are visible defects in the concrete, such as concrete spalling, or unevenness exceeding 4 mm void depth. The unevenness of concrete surface shall be verified by concrete surface tester.
- There is insufficient concrete cover. The concrete cover of the internal reinforcement shall comply with the valid design standard but at minimum shall be 10 mm. If the concrete cover thickness cannot be verified by e.g. existing technical drawings with great certainty, it is recommended to verify the concrete cover thickness by a concrete scanner device. If the concrete cover is insufficient, it should be increased by application repair mortar, concrete or shotcrete.
- There are cracks of more than 0.01 inch (0.25 mm) present[2]. Crack sizes can be measured with a crack width ruler. Care should be taken to seal cracks that may cause infiltration of water.[3]
- When active corrosion of reinforcement rebars is present.

If these conditions are not fulfilled, the thickness of the concrete cover shall be increased by adequate means, methods and materials. Further instructions on the adequate concrete patching can be found in e.g. DAfStb Guideline (Strengthening of concrete members with adhesively bonded reinforcement, Part 3: Execution, 2012); ACI 546R, ICRI 310.2R or DIBt TR. Information on treatment of cracks can be found in ACI 224.1R. Information for corrosion inhibition can find in the norm DIN EN 1504-9 principles 7–11.

The concrete surface needs to be dry, oil, dust-free and free of any chemically separating substances.

[1] It's essential to have an intact substrate without damaged or deteriorating concrete prior to installation of FRS-L-S and FRS-L-H CFRP Laminates. The FRS-L-S and FRS-L-H CFRP Laminates require an unimpeded bond to the substrate.

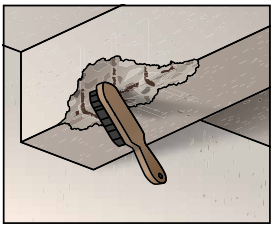
[2] Cracks > 0.254 mm (10 mils) are an indicator for movements in the structure that may affect the durability of the strengthening system. (ACI224.1R)

[3] Permanent moisture may affect the durability of the strengthening systems.

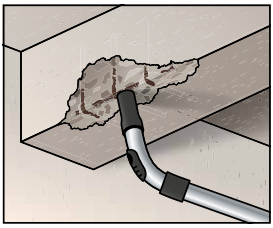
## 8.2 Concrete repair (optional)

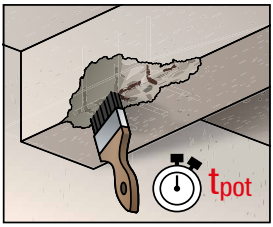
In most cases, concrete repair works on the damaged concrete surface are necessary prior to the CFRP Laminate installation. The concrete repair or concrete patching works shall be carried out by adequate means, methods, and materials, depending on the size of the damage and in accordance with the corresponding design standards. In the following, the concrete repair procedure is described using the components (FRS-PC 11 Epoxy Repair Mortar and FRS-BA Bonding Agent) of the fischer C-Fiber Force Strengthening System.

**Concrete repair works (optional)**



The damaged concrete fracture surface needs to be properly cleaned prior to the application of the concrete patching material or bonding agent. The concrete surface to be repaired or reprofiled must be dry, oil and dust free and the loose concrete parts must be removed. Tools such as steel brush, vacuum cleaner, compressed air might be used to clean the concrete surface.

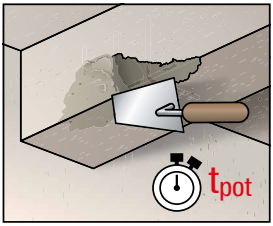





Apply the fischer FRS-BA Bonding Agent as a thin film layer on the concrete fracture surface using e.g. a brush. For the recommended thickness to be applied and detailed processing information please consult the TDS of FRS-BA.

Material consumption: 0.5–0.8 kg/m$^2$ FRS-BA is recommended.

Note that the material consumption is dependent on the surface roughness. The thickness of the applied film layer should be, if possible, verified by a wet film thickness gauge.




Apply the fischer FRS-PC 11 Epoxy Repair Mortar wet-in-wet into the concrete cavity with a spatula or trowel, which was beforehand primered with the FRS-BA Bonding Agent. Concrete cavities of 4–30 mm depth can be repaired using the fischer FRS-PC 11 and maximum 500 mm in longitudinal direction of the CFRP strengthening.

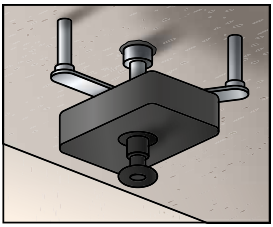
For the detailed processing information such as pot life, hardening times etc., please consult the TDS of fischer FRS-PC 11.

The material consumption of concrete repair mortar (FRS-PC 11) is primarily dependent on the size of the concrete cavity and it needs to be estimated prior to the project.

Note that according to DAfStb Guideline "Strengthening of concrete members with bonded reinforcement" and in accordance with the EAD 17-16-0086-03.01, the concrete repair works can be made with one of the following materials:

- Recommended material listed in the Technical Approval of the manufacturer (e.g. fischer FRS-PC 11 Epoxy Repair Mortar and FRS-BA Bonding Agent)
- Concrete grout with strength resistance class M3 according to DAfStb Strengthening Guideline
- Concrete according to EN 206-1 in connection with DIN 1045-1
- Shotcrete according to DIN EN 14487-1 in connection with DIN 18551

under consideration of the exposure class. The national regulations must be followed. The choice on the concrete repair material is the responsibility of the experienced structural engineer.

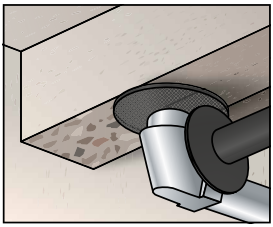


**Additional quality instructions**

According to the national regulations DAfStb "Strengthening of concrete members with bonded reinforcement" (2012) and according to our recommendation, if concrete repair works are executed prior to the actual CFRP strengthening, concrete pull-off tests must be executed on the repaired/reprofiled concrete surface before the application of the CFRP Laminate (see "Surface testing" below). The detailed procedure of the surface testing procedure is described in a separate manual.

## 8.3 Installation of CFRP Laminates on concrete surface

### Surface preparation



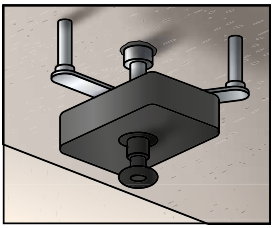
The concrete surface, where the CFRP Laminate will be applied must be roughened up by means of one the following techniques:

- Compressed air blasting with solid abrasives
- Shot peening
- Processing with a needle pistol
- Grinding (see figure)
- High-pressure water blasting

After the surface pretreatment, the coarse aggregates of the concrete ($D_{max} \geq 4$ mm) must be visible on the concrete surface. The roughened concrete surface enables the penetration of epoxy into the substrate and ensures proper adhesion. The remaining loose concrete parts as well as dust must be removed.

Care shall be taken of the national work safety regulations. It is recommended to indicate the final position of the CFRP Laminate on the concrete surface with a suitable and visible marker. The cleaned concrete surface should be protected until the very CFRP Laminate application.

### Surface testing



Prior to application of the CFRP Laminates, the suitability of the concrete surface must be verified through concrete pull-off tests. The concrete surface tensile strength is to be determined using concrete pull-off device. If concrete repair works were performed, the surface tensile strength is to be determined on the reprofiled concrete surface (see Section 8.2).

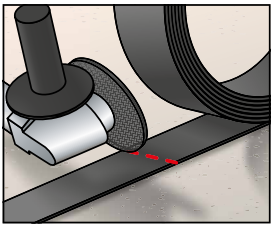
The concrete surface tensile strength must be measured by means of concrete pull-off adhesion testing device according to EN 1542 or according to ASTM C1583/ C1583 M after surface preparation.

At least five tests in different locations have to be performed. The number and position of the pull-off tests is the responsibility of the design engineer.

The characteristic mean concrete surface tensile strength must be at least $\geq 1.0$ N/mm$^2$ according to DAfStb Guideline (Strengthening of concrete members with adhesively bonded reinforcement, Part 3: Execution, 2012) or $\geq 1.4$ N/mm$^2$ according to ACI 440.2R (2017). If higher values are used in the structural design, these values have to be verified by concrete pull-off tests.

In case the requirement on the minimum concrete surface tensile strength is not met, the decision on the adequacy of the strengthening method with CFRP Laminates is the responsibility of an experienced structural engineer. The detailed procedure of the surface testing procedure is described in a separate manual.

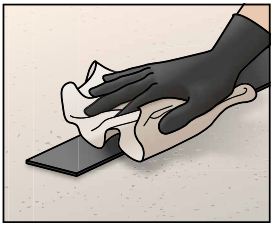
## Laminate preparation



Be careful when loosening the packaging straps off the CFRP coil because the uncontrolled uncoiling can cause injuries. The coils are under tension when they are coiled. It is recommended to use a coiler for CFRP Laminates.

The fischer FRS-L-S or FRS-L-H CFRP Laminates should be cut to the desired length e.g. using an angle grinder or hand saw. The longitudinal splitting of the CFRP Laminate must be avoided.

It is recommended to wear safety mask, safety glasses and safety gloves during cutting the CFRP Laminate.



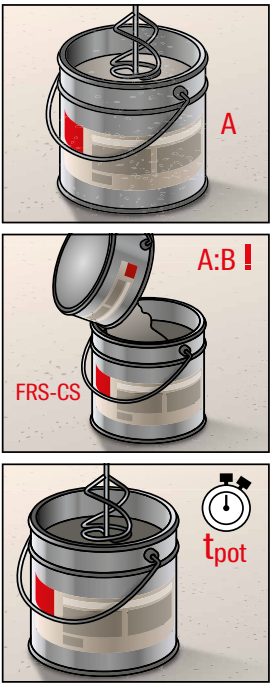
The surface of the CFRP Laminate, which will be later glued on the substrate, must be thoroughly cleaned using the fischer FRS-CA cleaning agent or acetone and a soft cloth.

The CFRP Laminate surface shall be completely dry, free of oil, dust and the entire length must be checked for visible damage prior to the application. Don't use damaged CFRP Laminates for example with visible cracks or spalling.

For reasons of quality tracking, it is recommended to bond the CFRP Laminates to the concrete substrate using the unprinted side. Note that principally both sides of the CFRP Laminate can be used for application and the printed logo has no negative influence on the adhesion.

Measures shall be taken to keep the CFRP Laminate surface clean until the very application.

## Preparation of epoxy mortar and CFRP Laminate installation




The two components FRS-CS Epoxy Mortar must be prepared by following the processing steps given in the TDS of FRS-CS. Note the required mixing ratio, pot life, storage temperature and the proper mixing procedure.

Special care should be taken of the work safety while working with fischer FRS-CS.

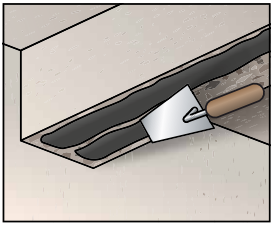
If phase separation is observed after opening the can components, the individual can components should be homogenized by stirring them separately, before mixing them. This is especially recommended when partial quantities are taken.

Add component B to component A and mix it (handheld agitator) for 3 min. with 300 rpm without air bubbles until a homogeneous and uniform gray tone is achieved.

If partial quantities are taken, please pay attention on the correct mixing ratio by weight of component A and component B (4:1). Using weighing scale is recommended for adhere the mixing ratio.

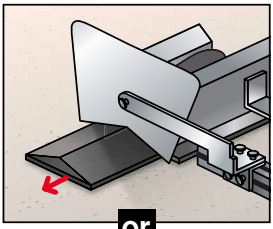
The temperature of intended use of FRS-CS ranges from 10 °C to 40 °C.

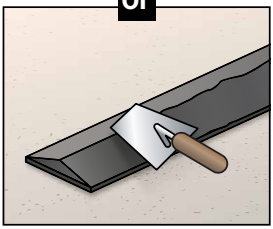
The pot life (working time) is 35–45 min. at 23 °C. The pot life is strongly dependent on the environment temperature and on the material quantity. Precooled material and processing smaller quantities can help to prolong the pot life.



A scratch coat of FRS-CS should be applied to the concrete surface and the CFRP Laminate applied wet-in-wet.

Concrete unevenness and minor defects no deeper than 4 mm might be directly levelled out using the epoxy mortar FRS-CS.





The mixed FRS-CS shall be applied on the surface of the FRS-L-S or FRS-L-H CFRP Laminate by either using the epoxy application device (see figure) or a spatula in a roof shape.

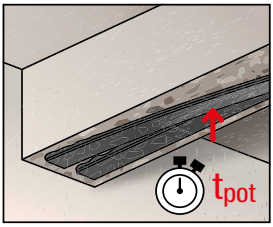
| Laminate width | FRS-CS |
|---|---|
| 50 mm | 0.3–0.4 kg/m |
| 75 mm | 0.4–0.5 kg/m |
| 100 mm | 0.6–0.7 kg/m |

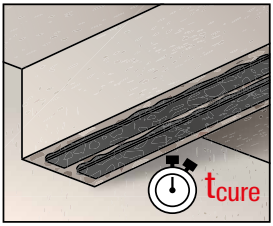
The required amount of FRS-CS may strongly depend on the concrete surface roughness, layout of CFRP Laminate crossings and layer thickness.

After exceeding the pot life of FRS-CS, the material should not be used. Note that the actual required quantity is strongly dependent on the concrete surface condition.

It must be ensured that the thickness of the adhesive between the laminate and the concrete surface is between 1 mm and 5 mm along the whole length of the laminate.

Care shall be taken of the calculation of the required amount of the FRS-CS, if laminate crossings are foreseen.




The FRS-L-S and FRS-L-H CFRP Laminates shall be gently pressed by using a hard rubber roller against the concrete surface until the excess material FRS-CS is visible on the edges of the CFRP Laminates. Remove the excess epoxy with a trowel. Avoid moving the CFRP Laminates once it has been attached to the surface.

The FRS-CS is able to carry the own weight of the laminate (≤ 40 °C) in overhead applications without additional temporary fixing solutions.

The unevenness on a distance of 300 mm must not exceed 1 mm.

In case of exposure other than classes X0, XC1 and XC3 according to DIN EN 1992-1-1 of CFRP Laminates a protective coating (FRS-SF) is required to prevent aging due to UV-radiation or permanent moisture

**Inspection and Quality control after the installation**

After the epoxy mortar FRS-CS has cured, the bonded surface is checked for voids by carefully tapping it or by means of pulse thermography or an equivalent method.

To verify the adhesion of the CFRP Laminate to the concrete substrate at least 5 pull-off tests according to EN 1542 or according to ASTM C1583/C1583 M should be performed on a reference CFRP Laminate placed in a representative location according prior to loading of the strengthened structural member.

The minimum requirement on the characteristic mean surface tensile strength is ≥ 1.0 N/mm$^2$ according to DAfStb Guideline (Strengthening of concrete members with adhesively bonded reinforcement, Part 3: Execution, 2012) or ≥ 1.4 N/mm$^2$ according to ACI 440.2R (2017) and the failure should occur in the concrete layer (concrete cohesion failure) and not at the CFRP Laminate-concrete interface. If a higher value was used in the structural design this value must to be verified.

The concept of the quality inspection plan of the strengthened structure or structural member is the duty of the responsible structural engineer, following the national and international regulations, such as AC 178, DAfStb-Guideline [2].

## 8.4 Installation of the CFRP Laminate on masonry and timber

In addition to reinforced concrete, the fischer FRS-L-S and FRS-L-H CFRP Laminates might be applied on timber and masonry. Ensure that the masonry structure is suitable for the installation of the fischer FRS-L-S and FRS-L-H CFRP Laminates. The system can be installed on moderately cracked surface, whereas crumbling bricks and poor substrate quality will compromise the quality and effectiveness of the strengthening system. The responsible specialist engineer must carry out the necessary inspection and calculations, eventually pull-off tests on site to verify the assumptions met during the structural design. Your national fischer subsidiary provides you with consultancy if required. For installation, remove dust completely with oil-free compressed air or vacuum and remove loose masonry parts.

# 9 Legal notes

The above information, in particular the suggestions for processing and use of our products, are based on our knowledge and experience under normal conditions, provided the products have been stored and used properly. Due to the different materials, substrates and deviating working conditions, a guarantee of a work result or liability, from whatever legal relationship, can neither be justified from these instructions nor from verbal advice, unless we are charged with intent or gross negligence in this respect. In this context, the user must prove that he has in writing all knowledge required for a proper and reasonable assessment by fischer, has been communicated to fischer thoroughly and on time. The user must test the products regarding their suitability for the intended use.

The product specifications are subject to change without notice. Third party property rights must be observed. In all other respects, our respective terms and conditions of sale and delivery apply. Always the latest product data sheet (TDS) applies, which should be requested from us.

# 10 References

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**fischer stands for**

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